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FARMERS' BULLETIN No. 1243 *rev.*

Rev. ed.
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Dec. 1927

The BORDER METHOD *of IRRIGATION*



THE PRIMARY PURPOSE of irrigation is to maintain an adequate amount of moisture in the soil around the roots of plants, and this can only be done by an efficient method of application. Crop yields in irrigation farming depend for the most part on the uniform distribution at the right time of the proper amount of water to the soil. The border method of irrigation described in this bulletin, while but one of several methods followed in Western States, is well adapted to a variety of soils and crops and is growing rapidly in public favor.

Washington, D. C.

February, 1922
Revised December, 1927

THE BORDER METHOD OF IRRIGATION

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THE BORDER METHOD of irrigation consists essentially in the division of the field to be irrigated into a series of strips,¹ lands, or beds, as they are variously termed, by low, flat levees extending usually in the direction of the steepest slope. Sufficient water is then turned into the upper end of each strip and this water moves down the slope in a thin sheet, moistening the soil as it advances toward the lower end.

ADAPTING METHODS TO LOCAL CONDITIONS

Crops are irrigated in various ways. About a dozen methods of applying water in irrigation have been more or less generally used in this country. This diversity is due to the varied conditions and requirements found not only in widely separated localities but also on farms of the same locality. In deciding upon a method of irrigation it is necessary to consider the amount of seasonal rainfall, the slope and general character of the ground surface, the amount of the water supply and how it is delivered, the kind of crop to be grown and the likelihood of a rotation of crops, and the porosity or imperviousness of the soil and subsoil. To these are usually added questions pertaining to cost, economy, and the permanency of the work to be done.

Sometimes a single requirement will outweigh all others. This holds true in a measure in the irrigation of truck crops in the Atlantic Coast States and throughout the humid region generally, where the spray method of irrigation is the most common. By means of parallel lines of overhead pipes, in which small nozzles are inserted at

¹ In an effort to standardize terms, the word "strip" has been used in this publication.

regular intervals, it is possible to apply very small amounts of water during dry spells without incurring the risk of putting on too much prior to a heavy rain or of damaging the truck crops by running water between the rows. Similarly in the irrigation of rice in the Gulf States the contour check with its modifications may be said to be the standard method. In western practice certain crops, such as potatoes, sugar beets, and corn, are planted in rows and cultivated, and for such crops the furrow method is preferable. Except, however, in the few general cases cited, the farmer may choose among several ways of preparing land and applying water, and it is not always easy to make a wise selection. Many farmers do not possess the requisite knowledge to make a choice, and instead of calling in assistance, they merely imitate what their neighbors have done, though it may not be the best for their needs. So common is this latter practice that one frequently finds large areas, made up of farms which differ widely in their physical condition, all irrigated in the same way.

CONDITIONS THAT FAVOR THE BORDER METHOD

A smooth, regular surface having a slope in one direction of about 2.5 inches to the hundred feet may be regarded as ideal for the border method of irrigation. It is possible to make borders on slopes 1 inch or less to the hundred feet and on steeper slopes up to 2 feet and more per hundred feet. Cases might be cited where borders have been used on slopes as great as $7\frac{1}{2}$ feet to the hundred feet, but extra care must then be taken to prevent soil and crop erosion.

The amount of water which can be turned into the strip depends on the size of each strip, its slope, and other conditions. In narrow, short strips the head used may be reduced to half a cubic foot per second or from 20 to 25 miner's inches, and in wide, long strips 10 cubic feet per second may be none too large. A large volume of water can not be handled successfully on steep slopes, but it is always possible to divide a head between two or more strips.

The kind of crop to be grown must usually be considered in connection with the rotation of crops. It seldom pays to prepare a field for the border method for one crop. Since this method is well adapted to the irrigation of alfalfa, clover, and other forage crops, and also of all grains, the forage crops may be rotated with the grains without modifying the method. It is also possible to irrigate potatoes, sugar beets, cotton, and other rowed and cultivated crops by making a slight change in the borders, so that the latitude as regards rotation is rather wide.

The most favorable soil for borders is a free-working loam several feet deep, underlain by a more or less impervious subsoil. As the sheet of water flows down each strip, the pervious top soil is readily moistened and the tighter soil beneath prevents the waste of water by deep percolation. Borders are also very generally used where the subsoil as well as the top layer of soil is porous, not because such formations are the most favorable but because no other method will do as well.

The cost of preparing land for the border method is low as compared with that required for most other methods if the physical conditions are favorable. Besides, it is usually feasible to obtain a

fair crop at small cost by the use of temporary borders, and after the crop is harvested, the making of permanent borders may be undertaken without undoing much of the previous season's work.

PREPARATION OF PERMANENT BORDERS

The chief preliminary operations in the border method consist in making the necessary surveys and in laying out the borders in accordance with the requirements of the farm and the physical conditions. Closely related to these preliminary steps are the location of supply ditches or pipes and the main laterals, and the determination of their capacity. These in turn bring up the subject of water supply, its delivery in rotation periods, and the various structures, such as gates, checks, siphons, and drops, required for its proper control. Then follow the building of border levees, the preparation of the ground surface between borders, and the disposal of any waste water which may occur. These features will be considered in the order given.

SURVEYS

In the subdivision of large areas of land such as townships, the customary practice of having square units containing 640 acres and 160 acres, respectively, possesses advantages over irregular surveys. On the other hand, a rigid adherence to square and rectangular tracts in laying out a farm for irrigation frequently places a handicap on the undertaking during its formative stage which no future modifications can well rectify. The reason for this is that for such farms the water supply is of first importance, and the shape and boundaries of the farm should conform to the water channels as well as to the configuration of the land surface, quality of soil, and other considerations.

The State Land Settlement Board of California has adopted with satisfactory results the logical plan of subdividing land for State colonies in conformity to the topography. In the plat of the Durham colony located in the Sacramento Valley of California, an outline of which is shown in Figure 1, the original land lines were seldom used as farm boundaries, but new ones were established more in accordance with the canal system, the character of the soil, and the productivity and value of the land. Where the soil is fertile and deep, the holdings are relatively small and were sold to settlers at \$200 to \$225 an acre; on heavier and less desirable soil the price ran from \$75 to \$180 per acre in larger lots, and some of the shallow land, fit only for grazing, was sold in still larger lots for as low as \$10 per acre.

Figure 2 is an enlarged sketch of farm lot No. 74 of the Durham colony showing 6-inch contours and two natural ravines. Figure 3 shows the same lot, together with the size and direction of the borders and the necessary supply ditches and drains.

In laying out farm systems of irrigation for any method of water application, contour surveys should first be made, especially if the surface is at all uneven or irregular. Such contours can readily be located and mapped by dividing the field into squares of 100 feet along the side and taking an elevation at each of the corners. The benefits to be gained by contour surveys in locating and building farm

ditches and borders, as a rule, far exceed the cost of such work. Besides, with the aid of such surveys the direction and size of the borders and the feed ditches or pipes can be sketched and staked out in the field in conformity to them.

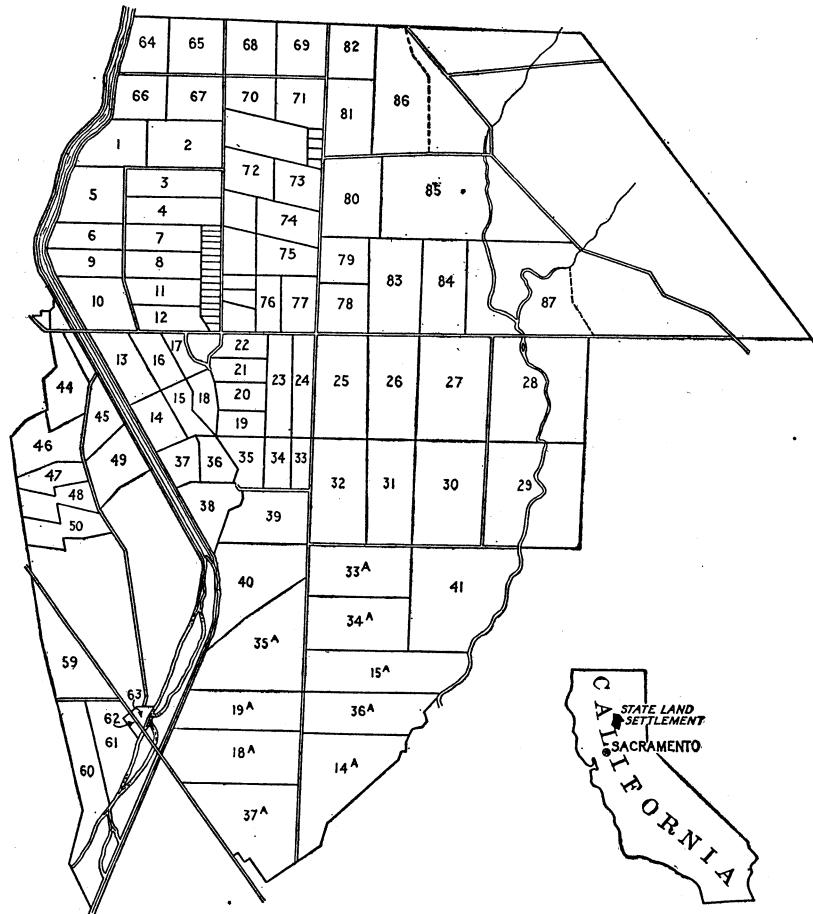


FIG. 1.—Outline of farm lots, and laborer's allotments on the Durham Land Settlement Colony at Durham

SUPPLY DITCHES AND PIPES

The location of the ditches or pipes which supply water to borders is fixed by the survey. Their capacity is gauged principally by the quantity of water which can be obtained from the canal system.

Canal companies and other irrigation agencies differ widely in ways of delivering water. Quantities delivered vary from less than 1 second-foot to more than 10 second-feet, and times of delivery from a continuous stream to rotation periods of 45-day intervals. Since the conditions which govern the delivery of water from any one system can seldom be modified by the water user, he is obliged to

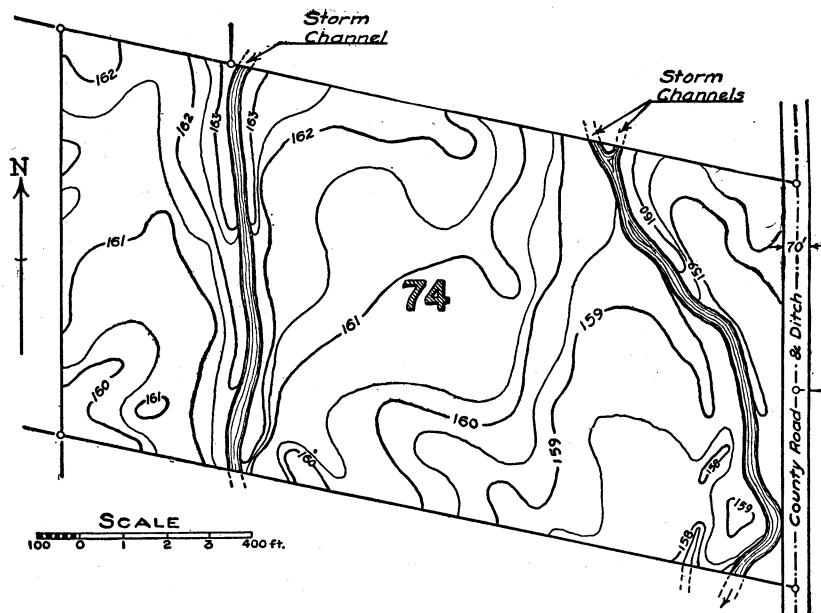


FIG. 2.—Farm lot No. 74 of the Durham colony enlarged, showing contours

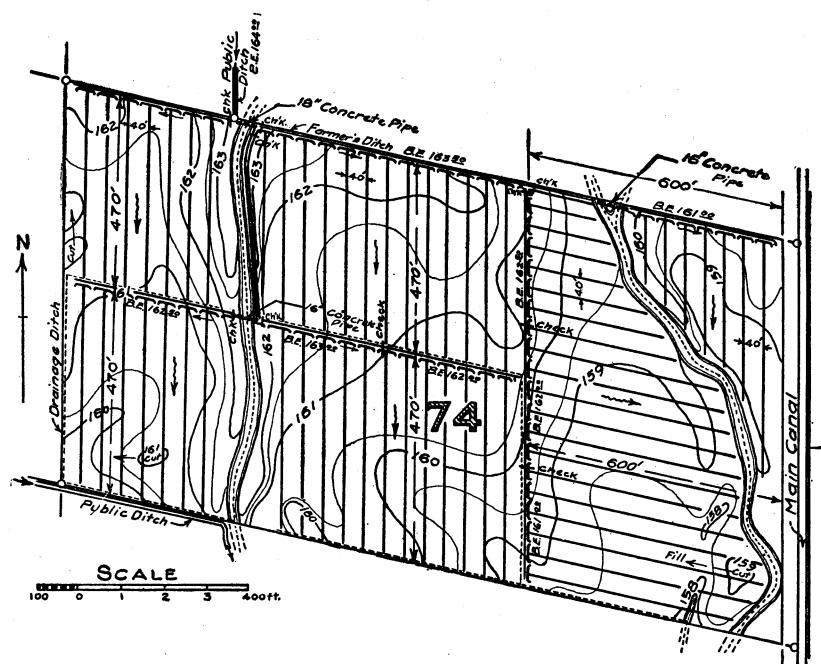


FIG. 3.—Farm lot No. 74, showing size and direction of borders and the necessary supply ditches and draws.

adapt the capacity of his supply ditches and borders to the quantity of water which can be obtained from the canal system at any one time.

Four types of supply ditches are shown in Figure 4. The form of these, in each case, is fixed somewhat arbitrarily, since the cross-section depends upon the kind of implement used in their construction.

Table 1 gives the mean velocity and carrying capacity of each of these typical supply ditches when running full, on a number of different grades.

TABLE 1.—*Carrying capacities of supply ditches under different grades*

[Computed by Kutter's formula, using $n=0.025$]

DITCH NO. 1: BOTTOM WIDTH, 16 INCHES; DEPTH, 6 INCHES; SIDE SLOPE, $1\frac{1}{2}$ TO 1

Grade			Mean velocity in feet per second	Carrying capacity			
Feet per 100 feet	Nearest $\frac{1}{8}$ inch per rod	Feet per mile		Cubic feet per second	Miners' inches		
					Under 6-inch pressure	Under 4-inch pressure	
0.2	$\frac{5}{8}$	10.56	1.04	1.08	43	54	
.3	$\frac{5}{8}$	15.84	1.28	1.33	53	67	
.4	$\frac{11}{8}$	21.12	1.48	1.54	62	77	
.6	$1\frac{1}{8}$	31.68	1.81	1.89	76	95	
.8	$1\frac{1}{8}$	42.24	2.09	2.18	87	109	
1.0	2	52.80	2.34	2.44	98	122	
1.2	$2\frac{1}{8}$	63.36	2.56	2.67	107	134	
1.4	$2\frac{3}{8}$	73.92	2.77	2.89	116	145	
1.6	$3\frac{1}{8}$	84.48	2.96	3.08	123	154	

DITCH NO. 2: BOTTOM WIDTH, 2 FEET; DEPTH, 9 INCHES; SIDE SLOPE, $1\frac{1}{2}$ TO 1

0.1	$\frac{1}{8}$	5.28	1.01	2.37	95	119
.2	$\frac{1}{8}$	10.56	1.45	3.40	136	170
.3	$\frac{1}{8}$	15.84	1.78	4.17	167	209
.4	$\frac{1}{8}$	21.12	2.05	4.81	192	241
.5	1	26.40	2.30	5.39	216	270
.6	$1\frac{1}{8}$	31.68	2.52	5.91	236	296
.8	$1\frac{1}{8}$	42.24	2.91	6.82	273	341
1.0	2	52.80	3.25	7.62	305	381
1.2	$2\frac{1}{8}$	63.36	3.56	8.34	334	417

DITCH NO. 3: BOTTOM WIDTH, 3 FEET; DEPTH, 1 FOOT; SIDE SLOPE, 2 TO 1

0.05	$\frac{1}{8}$	2.64	0.90	4.50	180	225
.1	$\frac{1}{8}$	5.28	1.28	6.40	256	320
.2	$\frac{1}{8}$	10.56	1.82	9.10	364	455
.3	$\frac{1}{8}$	15.84	2.24	11.20	448	560
.4	$\frac{1}{8}$	21.12	2.59	12.95	518	648
.5	1	26.40	2.89	14.45	578	723
.6	$1\frac{1}{8}$	31.68	3.17	15.85	634	793
.8	$1\frac{1}{8}$	42.24	3.66	18.30	732	915
1.0	2	52.80	4.09	20.45	818	1,023

DITCH NO. 4: BOTTOM WIDTH, 4 FEET; DEPTH, 1 FOOT 6 INCHES; SIDE SLOPE, 2 TO 1

0.05	$\frac{1}{8}$	2.64	1.21	12.70	508	635
.1	$\frac{1}{8}$	5.28	1.73	18.17	727	909
.15	$\frac{1}{8}$	7.92	2.12	22.26	890	1,113
.20	$\frac{1}{8}$	10.56	2.45	25.73	1,029	1,287
.25	$\frac{1}{8}$	13.20	2.74	28.77	1,151	1,439
.30	$\frac{1}{8}$	15.84	3.00	31.50	1,260	1,575
.35	$\frac{1}{8}$	18.48	3.25	34.13	1,365	1,707
.40	$\frac{1}{8}$	21.12	¹ 3.48	36.54	1,462	1,827

¹ Unsafe velocity for ordinary earth channels.

Farm ditches built in porous soil are wasteful of water because of the large percentage of the flow which is absorbed by the porous material. To prevent this loss and improve in other ways on methods of distributing and controlling water, pipes are beginning to take the place of earthen ditches. The kinds of pipes most commonly used for this purpose are concrete and a combination of wood and steel known as machine-banded pipe. Table 2² gives the capacity of concrete pipes of average construction, ranging from 6 to 36 inches in diameter and carrying from 0.5 to 20 cubic feet per second. The discharges are also given in miners' inches under both 4-inch and 6-inch pressure. An example of the use of this table, suppose that it is desired to find the velocity and loss of head when 5 second-feet, or 250 inches measured under a 4-inch pressure, is to be carried by a 22-inch pipe. In the column for 22-inch pipe and opposite 5 second-feet and the equivalent of 250 miners' inches we find that the velocity V will be 1.89 feet per second and the loss of head H will be 0.078 foot per hundred feet of pipe.

TABLE 2.—*The carrying capacity of ordinary concrete pipe of various sizes*

Quantity of water			6-inch		8-inch		10-inch		12-inch		14-inch		16-inch	
Sec- ond- feet	Min- ers' inches, 6-inch pres- sure	Min- ers' inches, 4-inch pres- sure	V	H										
0.5	20	25	2.55	0.724	1.43	0.158	1.83	0.196	1.27	0.075	0.94	0.034	-----	-----
1.0	40	50	5.10	2.880	2.87	.638	2.75	.442	1.91	.170	1.40	.075	1.07	.037
1.5	60	75	7.65	6.49	4.30	1.505	3.67	.795	2.55	.304	1.87	.135	1.43	.067
2.0	80	100	10.2	10.5	5.73	2.54	3.75	.795	3.82	.681	2.81	.304	2.15	.150
3.0	120	150	-----	-----	8.59	5.73	5.50	1.78	3.82	1.22	3.74	.539	2.86	.267
4.0	160	200	-----	-----	-----	7.33	3.15	5.09	1.22	3.74	1.22	3.74	1.22	3.74
			18-inch		20-inch		22-inch		24-inch		30-inch		36-inch	
5.0	200	250	2.83	0.225	2.29	0.129	1.89	0.078	1.59	0.050	1.02	0.016	0.71	0.006
6.0	240	300	3.40	.324	2.75	.186	2.27	.113	1.91	.071	1.22	.022	.85	.009
8.0	320	400	4.53	.577	3.64	.332	3.03	.201	2.55	.128	1.63	.039	1.13	.015
10.0	400	500	5.66	.898	4.58	.517	3.79	.315	3.18	.198	2.04	.062	1.41	.024
15.0	600	750	8.49	2.03	6.87	1.17	5.60	.685	4.77	.446	3.06	1.39	2.12	.053
20.0	800	1,000	11.30	3.59	9.17	2.07	7.58	1.26	6.37	.794	4.07	2.46	2.83	.094

BORDER STRUCTURES

The most common structures in border irrigation are the border gates to control the water entering each division or strip. These are made of lumber or concrete or a combination of the two. They may also be metal gates inserted in pipes. As in the case of supply or head ditches, the capacity of the gates varies from 1 to over 10 second-feet, and it is customary to design each of such a size that it can transmit the entire flow of the head ditch or pipe. Figure 5

² SCOBEE, F. C., AILEN, K., BENT, A. S., FINKLE, F. C., HAZEN, A., LIPPINCOTT, J. B., and NEWELL, H. D. THE FLOW OF WATER IN CONCRETE PIPE. U. S. Dept. Agr. Bul. 852, 100 pp., illus. 1920.

shows a standard single-wing gate of wood, which may be built in three different sizes, from 1 to 8 second-feet capacity, as outlined in the table of dimensions. Figure 6 shows a set of larger gates of the double-wing type, ranging in capacity from 3 to over 10 second-

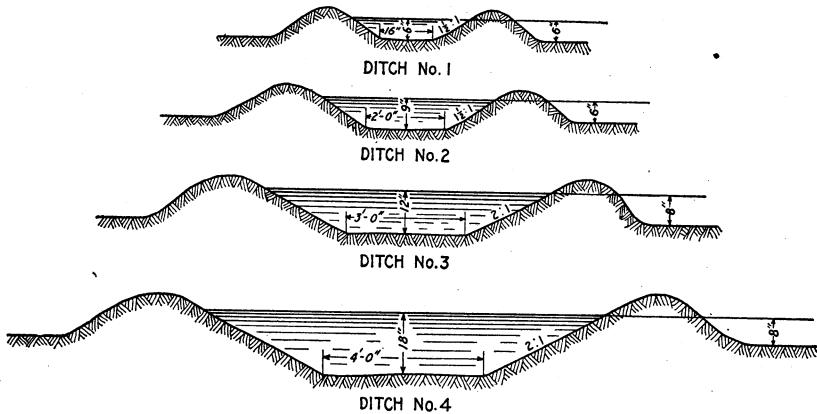
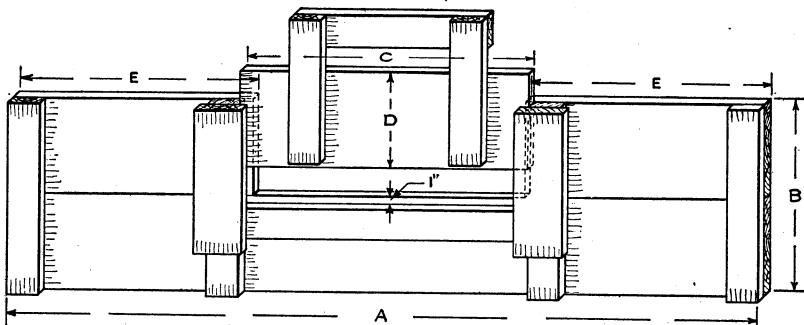


FIG. 4.—Cross sections of typical supply ditches

feet.³ The latter are used for the larger heads and in light, porous soils subject to erosion.

Because of the short life of untreated lumber when in contact with earth, border gates built of concrete are being used on a number

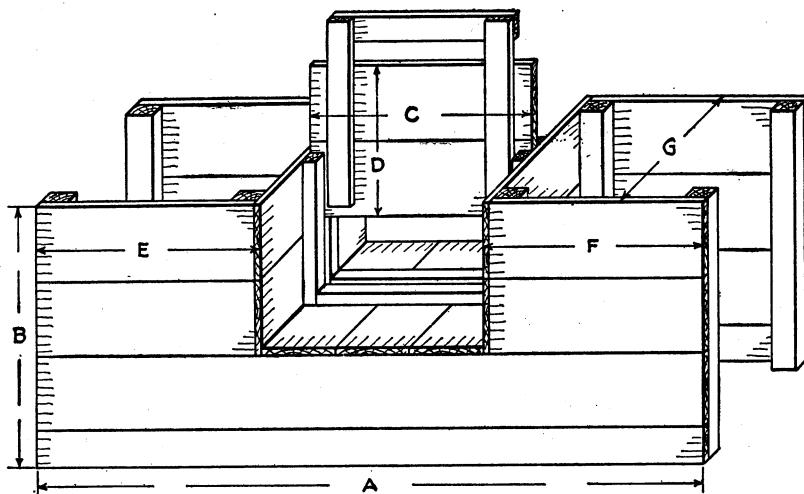


DESIGNED FOR HEADS OF	A	B	C	D	E	LUMBER THICKNESS
1 cfs. - 2 cfs.	8'-0"	2'-0"	3'-0"	1'-0"	2'-6"	1"
2 cfs. - 5 cfs.	9'-0"	3'-6"	3'-0"	2'-0"	3'-0"	1 1/2
5 cfs. - 8 cfs.	10'-0"	3'-6"	4'-0"	2'-0"	3'-0"	1 1/2

FIG. 5.—Standard single-wing wooden border gate

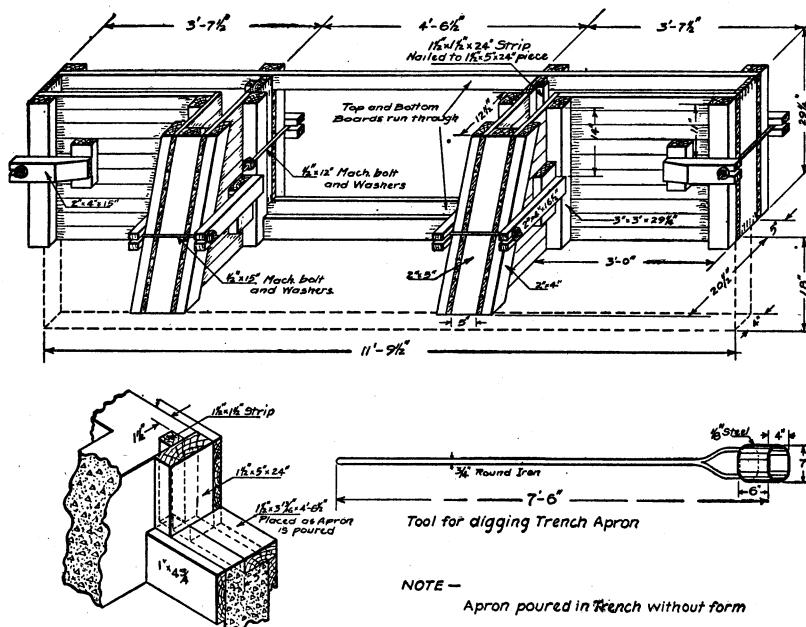
of canal systems. The design of lumber forms for one of this type is shown in Figure 7. Owing to the simplicity of this design and the ease with which it can be installed, the cost does not much exceed

³ The author is indebted to S. H. Beckett, of the University of California, for the designs of border or headgates shown in Figures 5, 6, and 7.



DESIGNED FOR HEADS OF	A	B	C	D	E	F	G
3 cfs - 6 cfs.	9'-0"	3'-6"	3'-0"	2'-0"	3'-0"	3'-0"	2'-0"
6 cfs - 10 cfs	12'-0"	4'-0"	4'-0"	2'-0"	4'-0"	4'-0"	2'-6"
10 cfs - AND UP	14'-0"	4'-0"	5'-0"	2'-0"	4'-6"	4'-6"	2'-6"

FIG. 6.—Standard double-wing border gate



Detail of Sill Form

FIG. 7.—Design of standard forms for concrete border gates

that of wood. Another form of border gate, also of concrete, used on the irrigation system of the Turlock district of California, is shown in Figure 8.

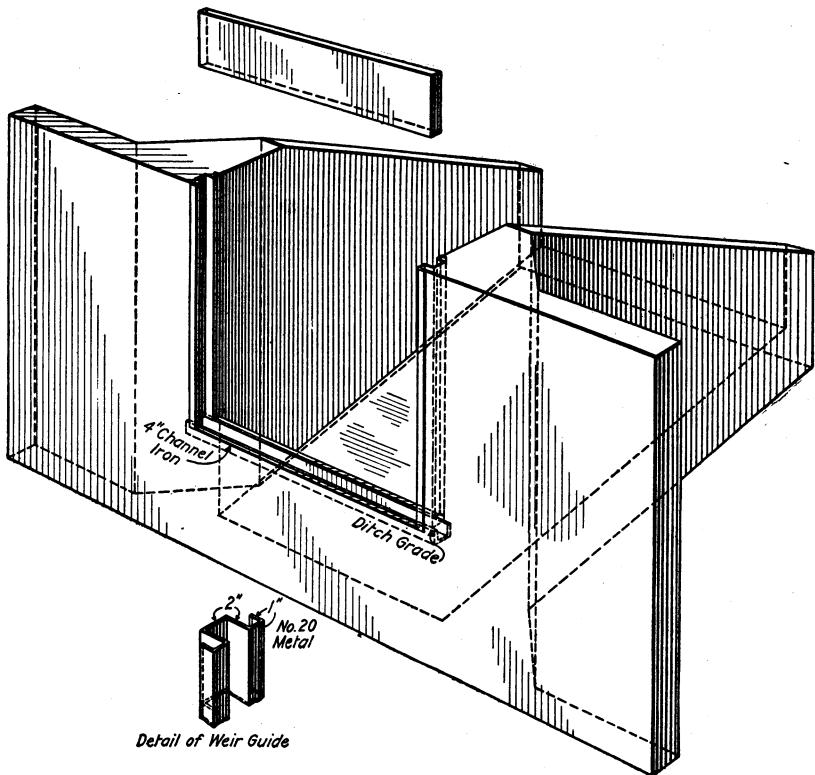


FIG. 8.—Outline of concrete gate and wooden flashboard as used on the Turlock irrigation district, California

When water is conveyed to borders through pipes, it is distributed to the head of each strip through short stands resting on the top of the feed pipe or on the top of short branch lines. In case concrete

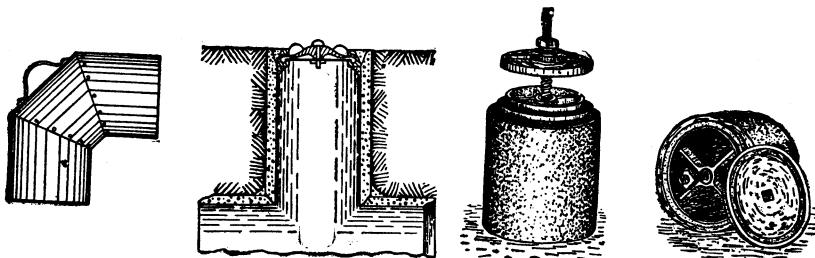


FIG. 9.—Metal valve inserted in concrete stand, and portable hood

pipe is used, the valve which controls the water is inserted in the top of the concrete stand, as indicated in Figure 9. To reduce the number of valves and thereby lessen the cost, one valve may feed

several strips in turn by means of a portable hydrant which is fastened to the stand and the requisite number of joints of galvanized surface pipe. A section of the portable hydrant having a connection for the surface pipe and the manner in which several strips may be watered from one valve are shown in Figure 10. A similar valve attached to a steel riveted pipe is shown in Figure 11.

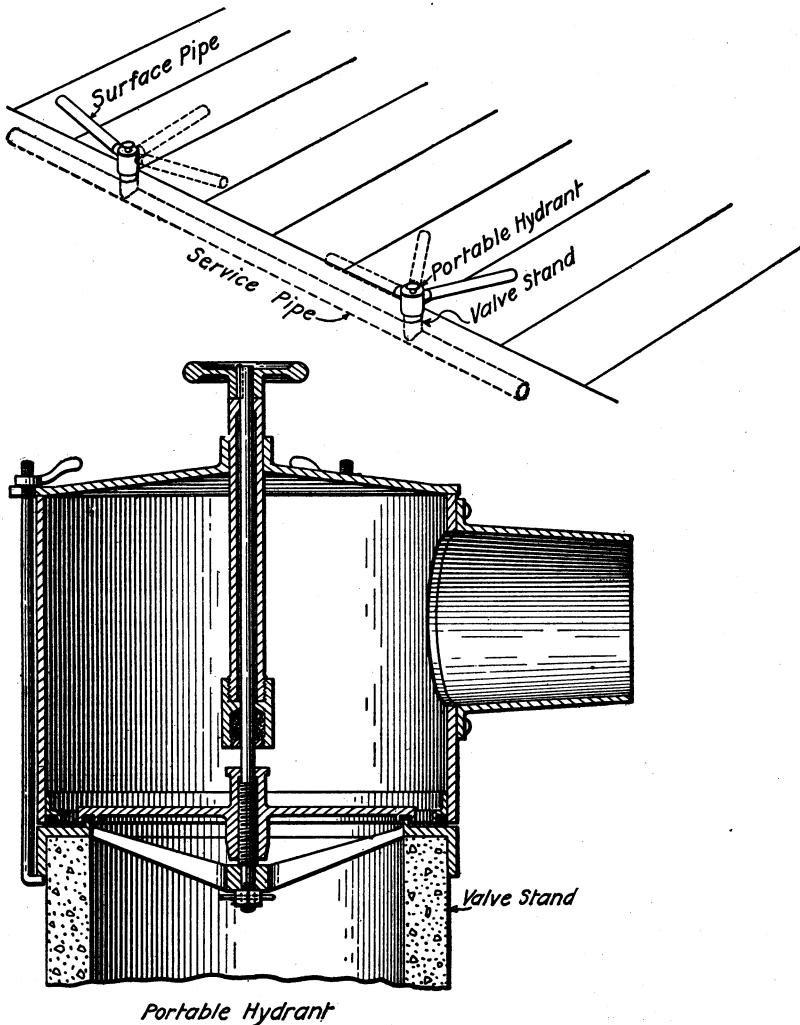


FIG. 10.—Portable hydrant attached to valve shown in Figure 9, service pipe, surface pipe and borders

When a check in the head ditch is needed to permit the full head to enter any one border gate, the canvas dam is about the cheapest and simplest device that can be used. It is advisable to have two such dams in order that one may be placed in the ditch at the proper distance below the one in use before the latter is removed. Even with this help the labor involved in shifting the dams from place to place

and the disagreeable nature of the task lead farmers to adopt whenever possible more permanent and less laborious methods. For this reason checks of wood or concrete with openings controlled by gates or flashboards are becoming more common. One of these, made of concrete with lumber flashboards, designed by R. V. Meikle, chief engineer of the Turlock irrigation district, is shown in Figure 12. If lumber throughout is preferred, such check gates may take the form of the double-wing border gate shown in Figure 6.

It is often necessary to divide the supply ditch into two or more parts by the use of a division box. One of these made of concrete is shown in Figure 13. It was designed and built by Milo B. Williams,

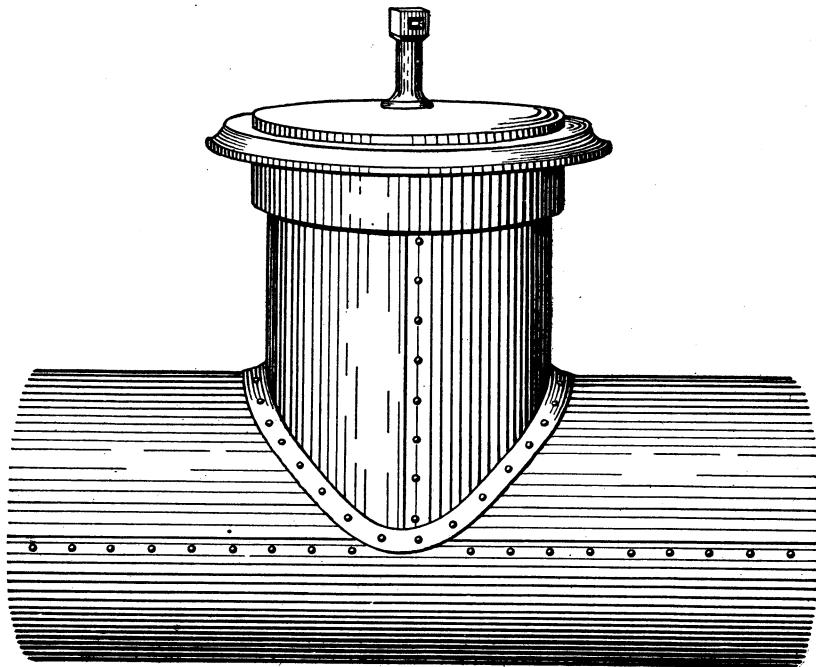


FIG. 11.—Valve for distributing water attached to a riveted steel pipe

of the Bureau of Public Roads, assisted by J. R. Jahn, of the California Land Settlement Board, for the land settlement colony at Durham, Calif.

When a supply ditch or other farm lateral crosses a stream, ravine, or other depression, a wooden flume on trestles has been the most commonly used structure. However, on account of the increased price of lumber and the likelihood of the early decay of wood, the use of pipes for this purpose, especially concrete pipes, has lately been rather extensive. Concrete and metal pipes are also being more frequently used for road crossings, in the form of culverts. In case the water flows through a culvert of this kind on grade, all that is necessary, apart from the pipe itself, is suitable protection at the inlet and outlet ends to prevent the soil around the culvert from washing away. This may be prevented by throwing up embankments of

earth or of mixed earth and gravel, properly puddled and packed, at each end of the pipe, or else by building head walls of concrete encircling each end of the culvert. If the bed of the ditch happens to be above the roadway, the concrete walls are replaced by concrete boxes, one of which serves as an inlet and the other as an outlet.

In other cases a road culvert may be combined with a check drop or division box, or two or more of these together, in which event the combined structure can be built more cheaply than could several separate and independent structures.

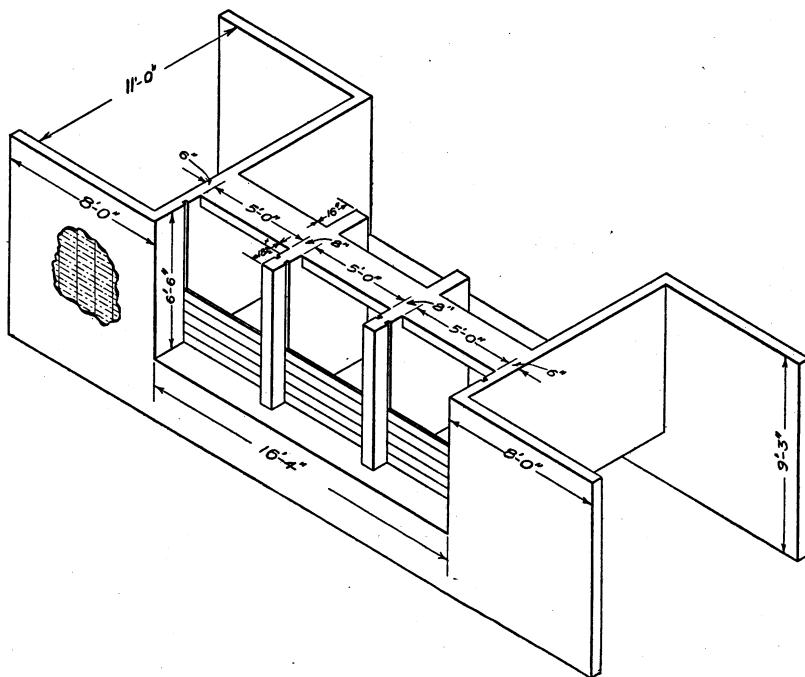


FIG. 12.—Concrete check gates on laterals of the Turlock irrigation district, California

PREPARING LAND FOR BORDER IRRIGATION

A survey of the field or farm is essential in order to locate the various farm ditches and determine the width, length, and direction of the borders. Such a survey should include the making of soil borings to ascertain the depth and character of the subsoil, whether any layer of hardpan is to be found within 6 feet or more of the surface, and, if within reach, the whereabouts of the water table.

The width and the length of borders vary with the head of water available, the texture of the soil and subsoil, the slope of the land, and to a less extent with the kind of crop grown and the amount of money available for such work. While the small-sized border tends to insure a more uniform moistening of the soil with the least waste of water, it necessitates the building and maintaining of more field ditches and structures and a larger number of field levees, both of which are objectionable features from the farmer's standpoint.

On the other hand, long borders in porous soils waste a large amount of water by deep percolation and are likely to show an uneven distribution of moisture in the upper layer of soil. In deciding upon the proper size of borders to use, certain factors such as the slope of the land and the character of the soil are more or less fixed, and it is only the size of the borders and the head which are subject to change. From this it is evident that a careful adjustment should be made so as to make the latter conform to the other main factors. For instance, in the question of the head to use, if the soil contains large percentages of clay and silt and does not moisten readily, the flooding of the surface with a large head for a short time might not wet the soil more than a few inches deep, whereas by allowing a small amount of water to run for a long period a much deeper penetration

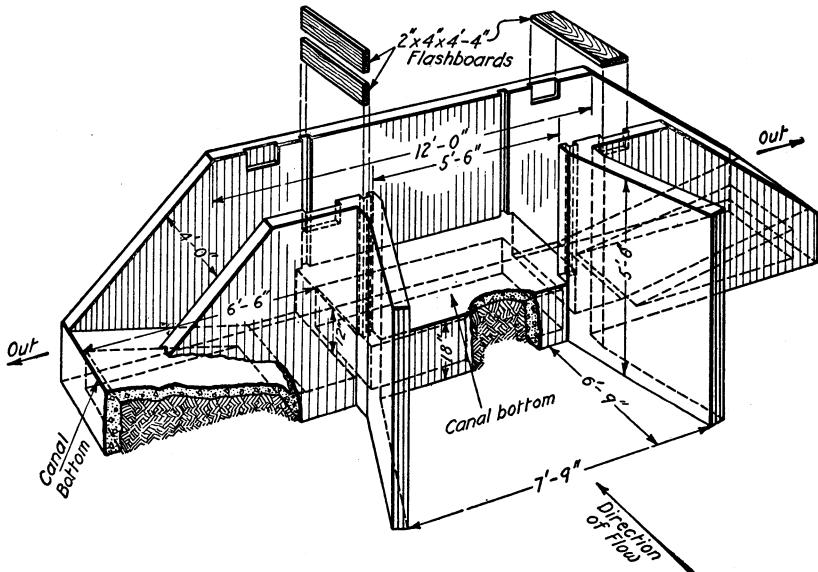


FIG. 13.—Concrete division box

of moisture can be secured. In the case of porous soils which absorb water readily there is a decided advantage in the use of large heads which move over the surface rapidly and thus prevent too deep penetration.

The field to be prepared for border irrigation is first plowed or disked. In case the soil is too dry and hard to allow this to be done successfully, it is watered as well as its nature will permit. Occasionally the ground is first leveled in a rough way by teams or tractors and afterwards divided into strips and borders. The location of the border levees is indicated by long stakes which may be made of half laths, and when these are set a straight plow furrow is run between stakes to mark in a more definite way the location of each border. A foundation for a border may be made by plowing two or three furrows on each side of the staked line, throwing the dirt toward the center. For small tracts the levees are built usually by the use of three-horse and four-horse Fresno scrapers, which are

driven back and forth at right angles to the levee lines. As the earth is scraped from the high spots it is carried forward and dumped on each levee in passing. The amount of earth dumped on each levee depends on how far the scraper loads are overlapped. If large levees are required, two or more scraperfuls of earth may be dumped in the same place, but in small, low borders, a slight overlapping of the loads may suffice.

The border levees, when first made, are composed of loose earth and are irregular in shape. To remedy the latter defect, several implements have been devised. One of these (fig. 14) is a wooden drag, trapezoidal in shape, drawn with the large end ahead. A common two-section drag harrow may also be used to advantage. A hinge should be placed in the middle of the evener bar, to allow the harrow to lap down over the sides of the levee as it is drawn lengthwise of the border.

After the levees are built the space between each pair is carefully leveled and graded by an implement somewhat similar in design to

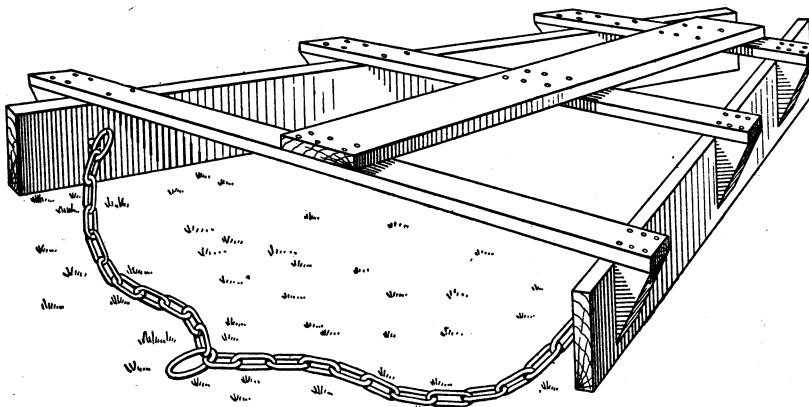


FIG. 14.—Drag used to prepare border levees

that represented in Figure 15. In properly prepared fields the standard requirement for this part of the work is that the surface shall be practically level crosswise between borders, the greatest variation in elevation permissible being about one-tenth of a foot. Such close attention to grading is necessary in order that the water may flow down the strip in a thin sheet of uniform depth. Otherwise it is certain to seek the lowest levels and may leave the higher spots unwatered or only partially watered.

Less attention need be paid to the grade in the direction of the border. It is not always necessary that the grade be uniform from top to bottom. It is desirable to make the upper end of the strip level, i. e., without grade, for a distance from the intake nearly equal to the width of the border strip. This causes the water, when first admitted through the gate to spread out sidewise and submerge all the space between the side levees before it begins to flow down the slope. The slope from this point to the end of the strip may or may not be uniform. To make a uniform grade often necessitates

the removal of a large amount of surface earth over considerable distances, which increases the cost of bordering and lessens the yields on the excavated portions. If the surface of the ground is such that a uniform grade can not readily be obtained, it is important to have, if practicable, the steepest grade near the lower end of each strip. The reason for this arrangement is that the water, as will be pointed out later, flows more slowly as it approaches the lower end, and if the grade in this part is increased it in turn causes the water to move faster and thus tends to produce a more uniform flow throughout.

The question of proper grades for borders may be better understood by a reference to the profiles in Figure 16, which indicate in each case the original surface of the ground before any grading or leveling is done and the established grade of the completed border. In the upper profile the natural slope of the ground does not vary

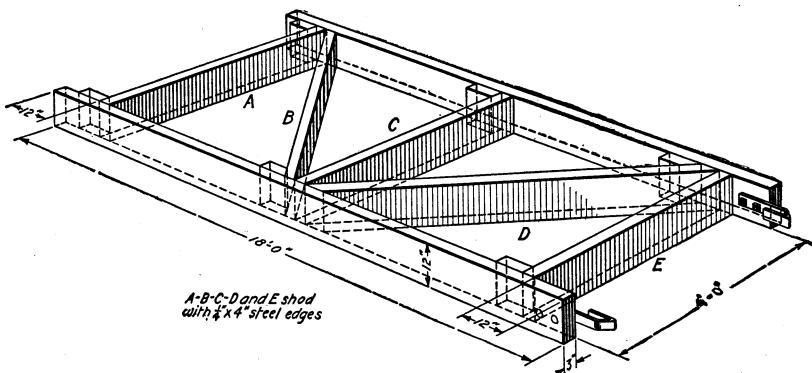


FIG. 15.—Rectangular drag for leveling land

much, and accordingly the grade of the border is made uniform throughout with the exception of the level part near the intake. In the next profile the surface is more uneven, calling for more earthwork in cutting down the high and filling up the low spots. A uniform grade is not possible in this case without heavy grading, involving extra cost, and to avoid both the grade is made to conform to the natural surface which has its greatest fall in the lower half. This is a desirable feature, particularly in long borders. The profile shown at the bottom of the figure is objectionable, chiefly because the slope is greatest in the upper part of the border.

SPECIAL METHODS USED IN PREPARING LAND

When the surface of the land to be irrigated is irregular, consisting of sand dunes or what are locally termed "buffalo" or "hog wallows," a tractor operating a large steel leveler or scraper is frequently employed to do the rough grading. Figure 17 shows one of these implements being operated by a tractor. Air is compressed by the tractor and conveyed through a pipe and hose to an air tank attached to the leveler in the rear. By means of the compressed air, the leveler is operated in an effective way, being readily forced into unplowed soil of more than ordinary compactness.

Border levees are sometimes made with a road grader (fig. 18). When this implement is used for this purpose the most common method followed is first to throw up a couple of back furrows with an ordinary plow to mark the location of each levee. The road grader then makes one trip around the back furrows, throwing additional earth on the levee thus formed. After this is done the grader is shifted to the center of the border strip and with each round crowds the surface earth toward the partially formed levee. For work of this kind the cutter should be set at an angle of about 45° . So set, ordinary graders cover a width of about 6 feet.

In compact soils great difficulty is sometimes experienced in getting irrigation water to penetrate to the depth of the lowest roots. It frequently happens that when water is applied in the usual way

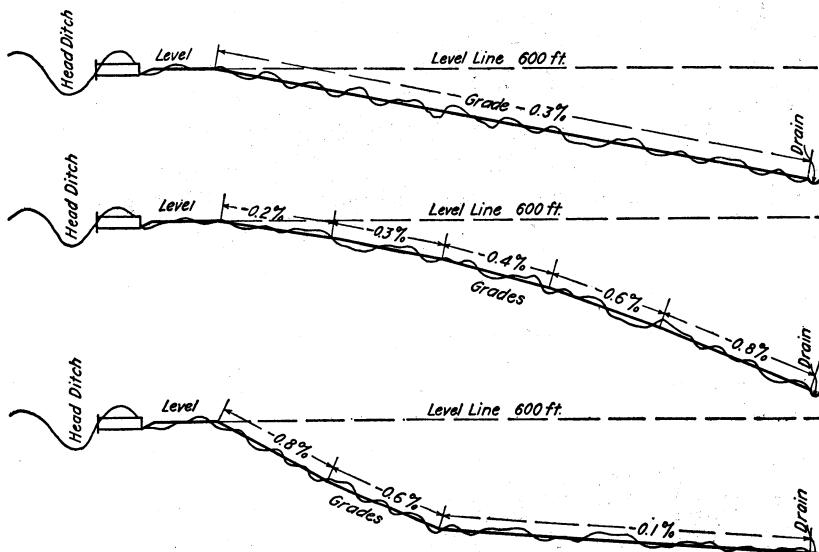


FIG. 16.—Profiles of typical border strips, showing surface before and after grading

such soils are not moistened beyond the top 6 inches. The running of a small stream for a long time over tight soils increases the depth of penetration. There are types of soil, however, to which this method will not supply sufficient moisture to the second and third foot of soil. In this event, the so-called check borders may be used to good advantage. This modification of the common border method consists in forming a low dike or ridge by two back furrows at right angles to the border levees and 100 feet or more apart, depending on the grade. With this change each border strip becomes a series of rectangular checks in each of which the water is impounded until the soil has been moistened to the required depth. By placing a piece of canvas over a low part of these cross dikes the water may be held in each for a considerable time, providing the temperature of the air and water is not high enough to scald such crops as alfalfa.

EFFICIENCY OF THE BORDER METHOD

The rate of advance of water as it moves down a strip may serve to indicate the efficiency of the application. Experiments conducted by P. E. Fuller and J. C. Marr, of the Bureau of Public Roads, in the

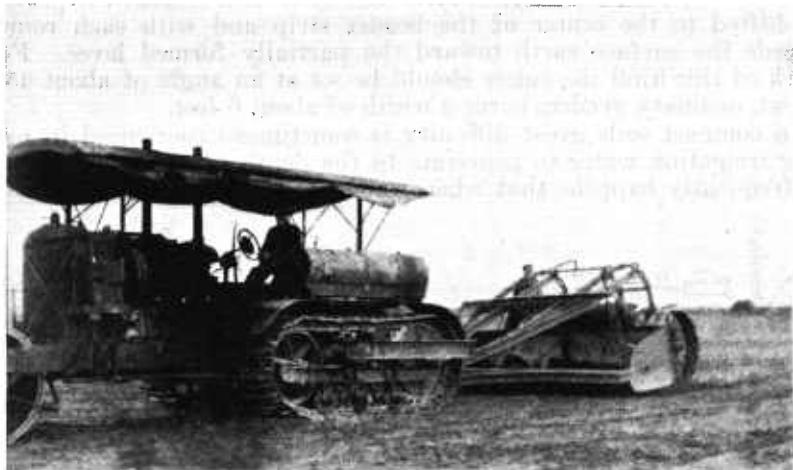


FIG. 17.—A caterpillar tractor drawing a land leveler

Salt River Valley of Arizona, using 8.5 second-feet of water in border strips 50 feet wide and 600 feet long (fig. 19), showed a slight decrease in the moisture content at the lower end, but on the whole the distribution of moisture was fairly uniform. On border



FIG. 18.—Road grader used in preparing land for border irrigation

strips 1,000 feet long (fig. 20) it was found that there was a fairly uniform distribution of water in the soil until the 600-foot station was reached, but, with the exception of the top foot of soil, little if any water penetrated into the soil near the lower end.

So long as the water advances at a uniform rate, the loss of water by deep percolation in porous soils is not great. On the other hand, when the runs are too long, the time required to irrigate the lower parts of the strips is much increased, causing a corresponding increase in the loss of water due to deep percolation. The remedy lies in the use of shorter runs and larger heads.

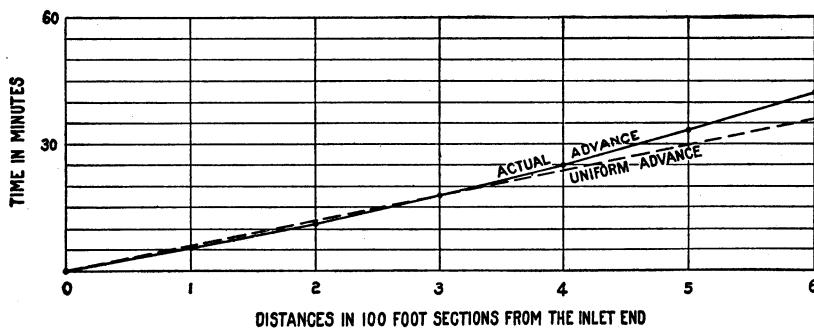


FIG. 19.—Rate of advance in a border strip 600 feet long

Another method which was employed by the author and W. W. McLaughlin, of the Bureau of Public Roads, to test the efficiency of an irrigation is to determine at what point the soil becomes so dry that plants begin to suffer. This is the so-called wilting point, which varies with the kind of soil, it being low in sandy soils and high in clay soils. In the lighter soils of the Salt River Valley, Ariz., it is about 5 per cent by weight of the dry soil. In the medium volcanic soils of southern Idaho it is about 10 per cent, and in the adobe

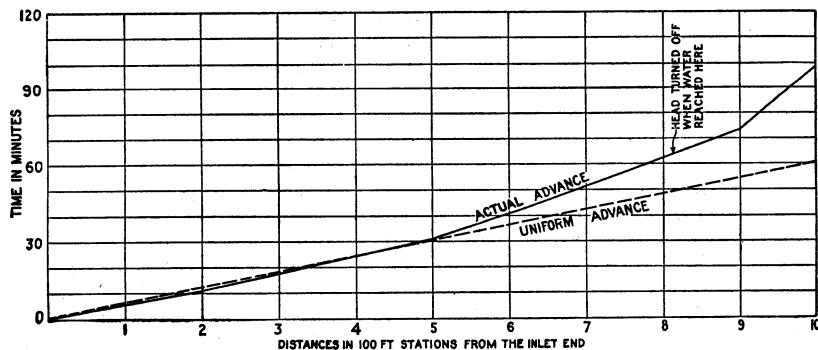


FIG. 20.—Rate of advance of water in a border strip 1,000 feet long

soils of the rice belt of California it is about 15 per cent. After the wilting point of the soil under consideration is determined, it is then necessary to ascertain what amount of moisture the soil will retain against gravity to a certain depth. Assuming the wilting point of the soil under test is 12 per cent and that its total water-holding capacity immediately after being irrigated is 24 per cent, the difference of 12 per cent when converted into acre-inches of water represents all that the soil will hold in a layer of known depth and all that should be applied at any one time.

ARIZONA PRACTICE IN PREPARING BORDERS

Prior to the growing of cotton on a large scale fully 75 per cent of the irrigated area of Arizona was watered by the border method, and although cotton, to a large extent, has taken the place of alfalfa as a staple product, borders are also extensively used in the irrigation of this crop. Invariably the first irrigation of cotton land is by the border method. Some growers prefer to level these out before planting, but very often they are permanently constructed and retained. Even though the crop be irrigated by the furrow method, as is usually the case, the borders aid in restricting the flow of water when furrows become clogged and, of course, constitute a permanent improvement in the rotation of cotton with crops which are usually irrigated by the border method in this locality. During the period when furrow irrigation is necessary smaller heads of water are delivered unless the force is sufficiently increased to handle the customary head.

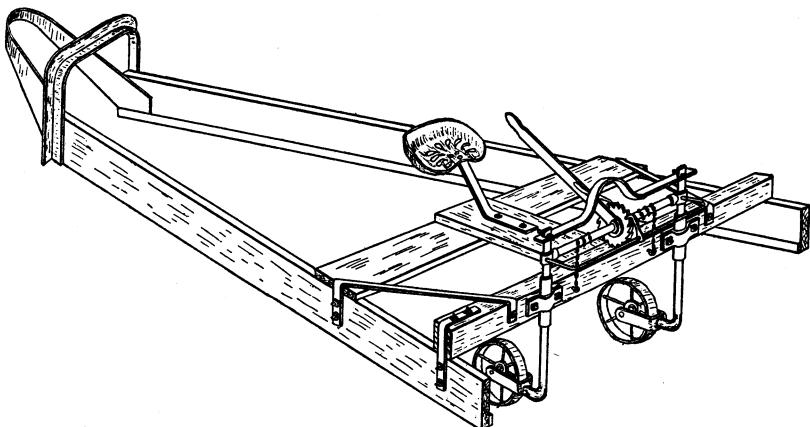


FIG. 21.—Bordering machine as designed and used in Salt River Valley, Ariz.

Much of the natural surface of the Salt River Valley is so smooth and the slope so uniform that little surveying is required preliminary to preparing borders.

The border disk is the most commonly used implement for constructing permanent borders, though sometimes the levees are formed by plowing two or three furrows on each side of the center line of the proposed border and then smoothing and shaping the ridge with one of the several border implements and a V ditcher. A company growing cotton has modified the ordinary trapezoidal ridger (fig. 14) by attaching a metal frame to the rear end for the purpose of reducing the top of the levee to an even grade and otherwise making it more regular. This device is shown in Figure 21. The space between border levees is smoothed and graded by a drag similar in design to that shown in Figure 15.

Large heads of 7 to 10 second-feet are the most common, but the manner in which these large heads are checked and diverted into the border strips varies somewhat. The simplest and least expensive

method is to check the flow in the supply ditch by a canvas dam and remove with a shovel a part of the lower embankment, allowing the water to flow into the border for about two hours or until the water has reached within 200 feet or so of the end of its run, when the earth taken out is replaced and the canvas dam shifted to a higher point.

The canvas dam (fig. 22) consists of a framework of lumber with a tarpaulin about 7 by 14 feet spread over it and pressed into the soft earth at the bottom and sides. The lumber usually consists of a round pole or sawed joist placed across the ditch with the ends resting on the banks. Then lighter poles are placed in a slanting

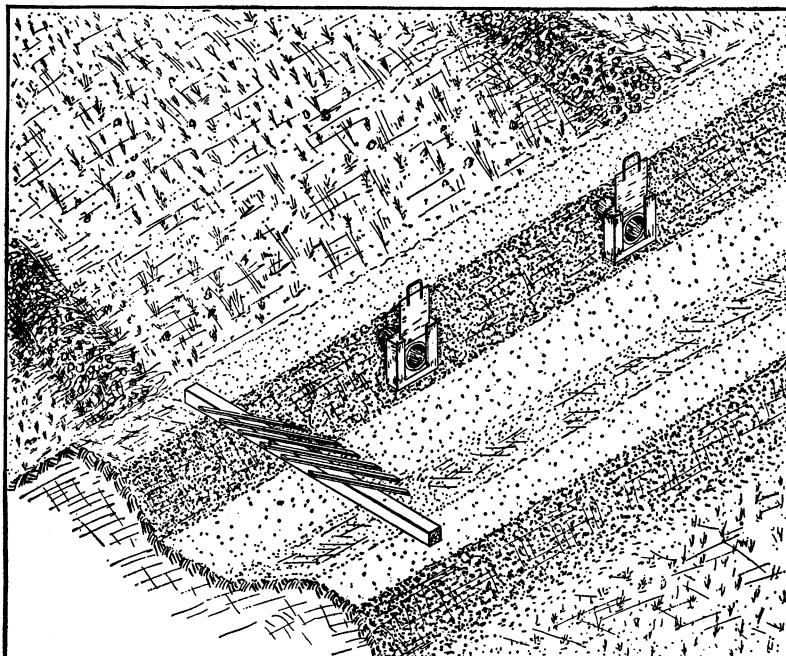


FIG. 22.—An Arizona head ditch with frame for canvas dam and two border gates

position on the upstream side with one end in the bottom of the ditch and the other resting on the crossbar. The latter is allowed to remain in place when not in use and the smaller sticks are placed on the bank beside it.

To lessen the labor involved in the method just described, it is common practice to install checks and border gates. These are made of wood or concrete and do not differ essentially from those already described. A border gate which is gaining in favor is made of several joints of concrete pipe of the required diameter with the upper opening controlled by a metal slide as indicated in Figure 22. In putting in such gates, care should be taken to tamp moist earth around them in order to prevent erosion at the bottom or sides.

In Arizona the most common width of border is 50 feet and the most common length one-quarter of a mile. Perhaps the chief mis-

take which has been made in preparing land for border irrigation in this State has been the adoption of long runs regardless of the type of soil. Where the soil is deep and porous, large quantities of water are readily absorbed and drawn down by gravity beyond the deepest roots. In this type of soil it is not possible to irrigate the lower end of a long strip without wasting the greater part of the water turned in at the head. The remedy is to divide a 40-acre tract into three belts with a head ditch for each, thus reducing the length of run to 440 feet or less. If the slope is suitable, a large head will advance at a fairly uniform rate over this distance without much loss by deep percolation and bring about a fairly even wetting of the soil.

On the other hand, in the case of clay loam soils, or of porous soils overlying impervious layers, a length of border of 1,300 feet or more is often warranted. Soil-moisture determinations have been made after an irrigation by engineers of the Bureau of Public Roads on borders half a mile long, which indicated a fairly uniform distribution of the water applied without appreciable loss, although the water was allowed to run for two to four hours on each strip.

THE BORDER METHOD AS PRACTICED IN NEVADA

The Bureau of Public Roads, in cooperation with the Nevada Agricultural Experiment Station, made an economic study of the use of water as practiced near Battle Mountain, Nev., in the wild flooding of native meadows, comparing the present practice of distribution and application with the more modern methods of borders, checks, and furrows, and recording the gain in profit resulting from the adoption of better methods of farming. Owing to the imperviousness of the soil in this locality, the water does not penetrate readily to sufficient depths without the aid of low cross dikes spaced 100 feet or more apart. The effect of these is to make border checks, in each of which the water is pooled until the soil is moistened to the required depth.

Where border irrigation is practiced in the valleys of the Humboldt, the borders are usually made both wide and long. The borders of the Lovelock Valley vary from 1,000 to 5,000 feet in length and from 60 to 90 feet in width, and large volumes of water are turned into them during the river's flood periods. In the preparation of these borders the field is first leveled with a grader and then marked off into borders. A large trapezoidal wooden frame, mounted on wheels and controlled by a system of levers, is then used to form the border levees, the entire practice being adapted to large holdings and the use of large heads.

On the Newlands Government project in Nevada there are rolling sand-hill lands which require large expenditures for grading before they can be made ready for growing crops. In preparing such lands for border irrigation the customary practice is to make a contour survey with contour intervals of 6 inches. From this survey the direction and amount of the slope and the location of the supply and drain ditches are determined. The surface is then roughly leveled by the use of tractors drawing large scrapers, which can be operated on sandy soils without previous plowing. On firmer soils deep plowing should precede the grading process. About 1,000 acres

were rough graded by tractors in 1917 at a cost ranging from \$26 to \$40 per acre. The making of the borders and the final smoothing and leveling were left to the individual settlers to perform. The usual size is 65 feet wide and 660 feet long on slopes running from one-tenth of a foot to 3 feet per 100 feet.

THE BORDER METHOD AS PRACTICED IN OREGON

The border method has not been practiced long in either Oregon or Washington, but the success which has attended its introduction in both States bids fair to make it popular wherever the conditions are suitable. It is well adapted to conditions in the Willamette Valley and it will doubtless be very generally practiced when the lands now dry-farmed are irrigated. This method is being used for grain and fodder crops on peat and tule lands in the central part of the State east of the Cascades. It is also being used successfully on the light



FIG. 23.—Small borders for porous soils as practiced on the Umatilla Project in Oregon

soils, some of which are blow sands of the Columbia River basin. On the Umatilla project near Hermiston, Oreg., the average duty of water in 1912 was 9.7 acre-feet per acre, but in 1919 it was reduced to 5.65 acre-feet per acre. The more economical use of water on this project has been brought about largely by the adoption of small-sized borders (fig. 23) and the delivery of large heads in rotation periods. R. W. Allen, formerly superintendent of the Umatilla branch experiment station, and his successor, H. K. Dean, have investigated for years the best methods of irrigating the light soils of this project, and the results of their labors can be applied profitably throughout the West on the lighter type of porous soils. The following extracts from a circular on "Border Irrigation for Porous Soils," by R. W. Allen, will convey some idea of the essential features of this method as adapted to this type of soil:

As a result of eight years of study of methods of irrigating porous soils at the Umatilla branch experiment station and observations made of the success and value of different methods of irrigation on porous soils on many irrigation

projects throughout the West, it has been found that border irrigation offers the best-known means of applying water to soils of an open, porous, sandy, or gravelly nature.

The width, length, and shape of the borders should depend upon the character of the soil, slope of land, and the size of the head of irrigation water available. On coarse soil they need to be small so as to be quickly covered to prevent waste of water by deep percolation. On shallow soil they should be made small enough to irrigate quickly, in order to prevent excessive irrigation and the consequent complications of a water-logged soil or seepage spots in the field.

The length of borders should range from 70 feet on very coarse or steep soil to 300 feet on moderately sloping land of fine texture and good depth. The average length of borders should be about 200 feet. The width ranges from 20 to 40 feet.

On land having rough topography the borders can be made with a minimum of expense in grading by making them in a variety of shapes to conform to the slope of the land, V-shaped, fan-shaped, and L or crescent shaped borders are not uncommon.

It pays, and pays big, to have land in good condition for irrigation. The following data on two tracts of land show actual conditions on this project. Both tracts are of the same size, have similar soil, and were irrigated by the same man.

An irrigation head of $3\frac{1}{2}$ second-feet of water was used. To the first plot $3\frac{1}{2}$ inches of water was applied in 1 hour at a labor cost of $12\frac{1}{2}$ cents; labor figured at \$3 for a 24-hour day. To the second plot, $16\frac{1}{4}$ inches of water was applied in $4\frac{3}{4}$ hours at a labor cost of $59\frac{3}{4}$ cents per acre.

The first field was bordered and well leveled, with turnout boxes of good size. There is no duplicate irrigation. This saves time and water. Time and water saved is money saved. The second field was irrigated by free flooding. The land is uneven. Water is hard to control. The effect is duplicate irrigation, loss of time, and waste of water. Time and water wasted is money lost.

The levees, when made, should be about 18 inches to 2 feet wide and 1 to $1\frac{1}{2}$ feet tall. As soon as the land is graded, it should be irrigated to settle all loose places and to determine how the water flows over it. While water is on the borders, it is a good practice to get in with whatever implements are necessary and do all the work needed to make the water flow perfectly. Working this character of soil wet does it little if any damage.

As soon as the land is properly leveled for irrigation, precaution should be taken against wind erosion. It should be covered lightly with straw, about one-half to three-fourths ton an acre, and sown to rye at the rate of 30 to 40 pounds an acre. Where the soil is very sandy and subject to serious erosion and when irrigation water is not available with which to insure rapid growth of the rye, extra care should be used to prevent erosion.

The straw should be made fast to the ground by running over it with a disk harrow set straight to bury part and leave the remainder standing in the air. This serves as a windbreak by reducing the velocity of the wind at the surface of the land. Coarse manure or fine brush can be used to advantage instead of straw.

Suggestions to new settlers on the Umatilla project regarding cultural and irrigation methods in farming blow sands have been issued by Paul S. Jones, formerly connected with the Umatilla branch experiment station. The most pertinent of these suggestions which relate to irrigation are summarized in what follows:

As regards the construction of supply ditches, in most cases the settler builds them of too small capacity for economical irrigation. They should have a capacity of over $2\frac{1}{2}$ cubic feet per second. In many cases heads of 3 to 5 cubic feet per second can be used without excessive erosion.

After a supply ditch is staked out, it is well to smooth a strip along its course 25 feet wide above the ditch line and about 50 feet below. This work consists in grading to a uniformly smooth surface all

hummocks and depressions within this area by the use of Fresno or buck scraper and a rectangular float. The border levees are then built from 30 to 50 feet apart and from 150 to 300 feet in length. As each strip is completed it should be thoroughly irrigated.

Particular care in handling the water is required until the land is cropped, when the plant-root systems and surface growth will retard the flow of water and minimize erosion.

After the first irrigation is applied, the rectangular float may be again used for a final smoothing, after which rye is drilled in (over levees and all), sowing an extra amount at the upper end of each strip where more or less erosion usually takes place. Straw or manure covering is then disked in, the disks being set straight to press in the straw and so as not to roughen the surface. (Fig. 24.) The area thus protected has the appearance of a stubble field.



FIG. 24.—Disking straw to prevent wind erosion on borders of Umatilla Project, Oregon

Just as soon as the rye forms a protective covering, drill in the alfalfa seed immediately after a thorough irrigation over levees and all. If the growing rye should later threaten to choke out the young alfalfa plants, it may be clipped at intervals to relieve this condition.

From this stage on the surface soil must be kept moist by frequent light irrigations until the alfalfa plants are 3 or 4 inches high. This is the critical time in the life of these plants, and they will not survive if not given the much-needed surface moisture.

For a number of years experiments have been carried on at the Umatilla experiment farm near Hermiston, Oreg., to determine the proper length and width of border strips for the porous soils of that locality. The lengths adopted were 100, 175, and 250 feet and the widths varied from 20 to 40 feet.

On the Umatilla project check gates, drops, and turnouts are commonly made of concrete without the use of lumber forms. The banks are first put into proper shape and the concrete is then plastered

over the surface to be covered. The gate grooves are formed by inserting the gates into the green concrete before it is set. This somewhat novel construction is shown in Figure 25.

THE BORDER METHOD AS PRACTICED IN IDAHO

A large part of the irrigated land of Idaho is underlain with rock of volcanic origin. Owing to the porosity of this lava rock and to numerous cracks and fissures, a large percentage of the water used in irrigation is lost by deep percolation. Careful studies have indicated that the loss from this cause has frequently amounted to over 60 per cent of the water applied to the more porous types of soils.

The practice, still too common under private-irrigation enterprises in Idaho, of delivering water in continuous streams instead of in rotation is another cause of waste. A common stipulation of water-right contracts is that water shall be delivered continuously during

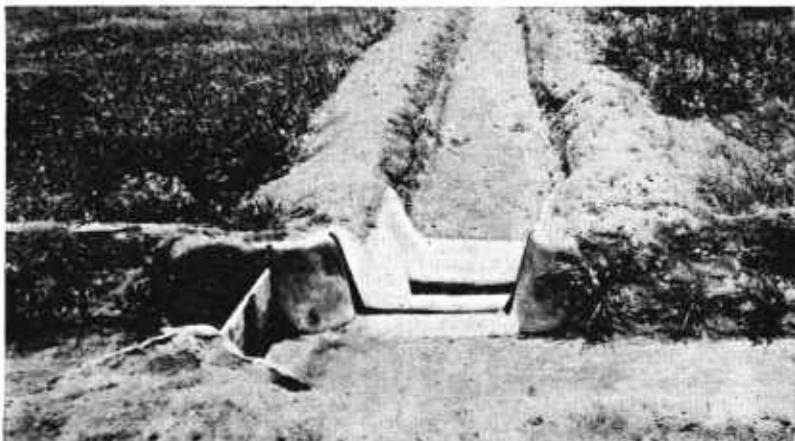


FIG. 25.—Check gates and drops made by plastering concrete on the sand as used on the Umatilla project, near Hermiston, Oreg.

the season at the rate of 1 second-foot for each 80 acres of land, and where the farms are 80 acres or less the amount is altogether too small for a serviceable or economical head. A great saving in water and labor could be effected and larger yields obtained by the use of 4 second-feet every eighth day on a 40-acre farm.

In cooperative investigations by the Bureau of Public Roads and the State of Idaho the amount of water used on 52 typical borders in different parts of the State was determined. These borders varied from 16.5 feet to 100 feet in width, averaging 67 feet, and the length varied from 250 to 2,560 feet, averaging 1,335 feet. The heads used varied from 1.4 to 7 second-feet and the depths of water applied at each irrigation from less than 2 inches to over 2 feet.

On a field of red clover near Rigby, Idaho, composed of gravelly soil, the borders were 2,359 feet long. On August 25, 1910, when the second crop of clover was 14 inches high, $2\frac{1}{4}$ second-feet was turned into one of these long borders. The water advanced over one-seventh of the distance, or 337 feet, in 1 hour and 22 minutes,

applying to the soil of this upper portion an average depth of $7\frac{1}{2}$ inches. The velocity of the water, however, became less and less as it advanced, and it required 7 hours to traverse the last 337 feet. The total time required to irrigate the strip was 22 hours and 42 minutes and the average depth of water applied was 20 inches.

The test just described calls attention to a prevalent defect in the border method as practiced in the sandy and gravelly soils of the State. The remedy which is being applied gradually is to use more head ditches, shorter runs, and larger heads of water.

In Idaho border levees are sometimes made by earth taken from each side, but unless these depressions are refilled in grading between border levees the bulk of the water flows within them, leaving the center of the strip dry or only partially watered. The Idaho method of making borders is illustrated in Figure 26.

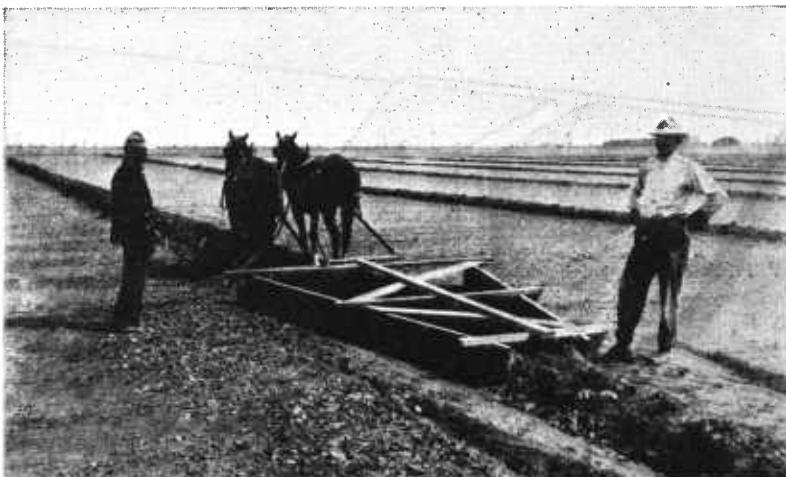


FIG. 26.—Preparing land for the border method of irrigation near Twin Falls, Idaho

Another practice is to make corrugations or small furrows between the border levees when the alfalfa or grain crop is seeded, so as to facilitate the even distribution of water during the first stage of crop growth. Similar furrows are also used on steep border slopes to prevent the erosion of young alfalfa plants by the action of large heads on sandy soil. By the time the small furrows fill with earth and sediment the alfalfa is well established by deep rooting.

THE BORDER METHOD AS PRACTICED IN SOUTHWESTERN TEXAS

On about one-half of the irrigated land in Texas, exclusive of the rice belt, the border method is used. If Arizona presents one extreme in the use of long borders, Texas presents the other in short ones. The largest areas inclosed between border levees are intended for the irrigation of alfalfa and grain, but these seldom exceed 25 feet in width and 330 feet in length. As might be expected, the levees and the heads of water used are correspondingly small. A large part of the water is derived from pumping plants, and the

heads vary from 200 to 1,500 gallons per minute, or from less than one-half a second-foot to over 3 second-feet. Where gravity water is available, the heads vary from 1 to 5 second-feet. The head or supply ditches are built in earth as a rule, with their lowest portion about on a level with the ground surface. The grades vary from one-half to 1 inch per 100 feet, and the cross-section is sufficient to carry the amount of water available. If the head is small, a metal tappoon is often used as a temporary check gate in the supply ditch. In the case of large heads, the water is checked by the canvas dam or by permanent check gates of wood or concrete.

In the irrigation of truck crops on the lower Rio Grande, the strips or "beds," as these are locally termed, are made much smaller than they are for forage and grain crops. Common sizes for truck crops vary from 10 to 15 feet in width and from 100 to 200 feet in length. The levees for such strips have a base width of about 3

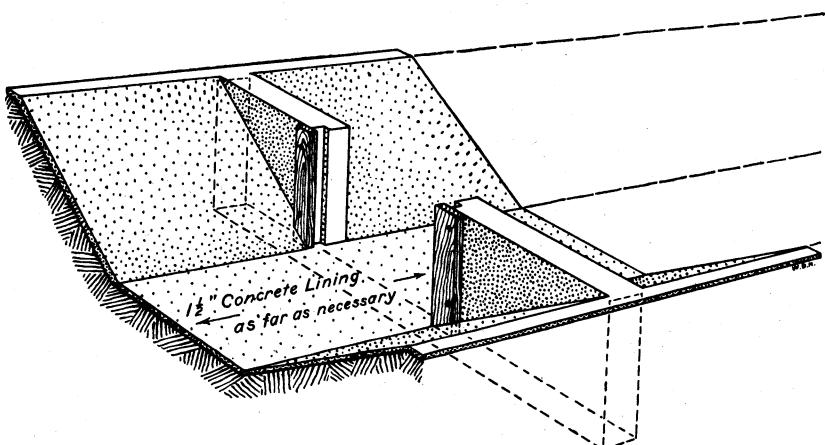


FIG. 27.—Check gate used on the Orland project, near Orland, Calif.

feet and a flat crown of about 6 inches when settled. When so built, they offer little obstruction to the passage of farm implements or loaded wagons. These levees are made in raw land by dirt removed from the high spots by graders or scrapers. When the land has been in cultivation they are made by two or four back furrows to start with and finished off by the use of a buck scraper, crowder, or road hone.

The time required to irrigate Texas borders depends on the soil and the volume of water turned on. A border 25 feet wide and 300 feet long may be watered in 15 minutes to an average depth of 2 feet in loam soil by a head of 900 gallons per minute or 2 second-feet. In tight soils smaller heads should be applied for longer periods so as to allow the water to penetrate into the soil the required depth.

THE BORDER METHOD AS PRACTICED IN CALIFORNIA

The greater part of the arable and irrigable land of California is adapted to the border method, particularly in the Sacramento, San Joaquin, and Imperial Valleys. Because of the wide variation in the

absorptive properties of soils and in the quantities of water delivered, the sizes of border strips vary. According to Beckett and Robertson,⁴ the border strips in the Sacramento Valley range from 30 to 120 feet in width and from 60 to 1,750 feet in length, the usual width being from 30 to 50 feet and the usual length from 400 to 700 feet. The same authors recommend that the heads used on the heavy soils be not more than about 40 per cent of those used on the medium loams. They also emphasize the necessity of a proper relation of the quantity of water used to the type of soil, and the size of each strip irrigated. The most common border gates used in this valley are shown in Figures 5 and 6. A concrete check gate in which some lumber is used, similar in type to that shown in Figure 27, is very generally used on the Orland project.

In the San Joaquin Valley, when the lands which had been devoted to grain raising under the natural rainfall were first irrigated, the custom was to use large rectangular or contour checks surrounded by heavy levees. In the later practice the checks were reduced in size but without a corresponding reduction in the size of the levees. In recent years many of these checks have been converted into borders, but the border levees as a rule are still too large, making it difficult to cross fields with farm implements.

In preparing new land for border irrigation in the medium loam soils of this valley, the best practice seems to call for borders not over an eighth of a mile long and about 50 feet wide, with low, flat levees which do not interfere with farming operations. Where the surface is rolling and the soil porous, the borders are small. On the State land settlement at Delhi, Calif., the borders vary from 15 to 30 feet in width and from 300 to 600 feet in length, with grades of one-tenth of 1 per cent to 6 per cent and heads of one-half a second-foot to 2 second-feet. The water for this colony tract is conveyed and distributed in concrete pipes ranging from 6 to 30 inches in diameter; hence most of the structures which are installed differ essentially from those used on gravity systems and earthen channels. The customary supply ditch in earth and the border gate are supplanted by a pipe with its top about 2 feet below the ground surface, from which branches a short length of smaller pipe terminating in a standpipe in which a metal valve is inserted. The concrete standpipe valve and hood are shown in Figure 9. Portable hydrants (fig. 10) are taking the place of the hoods. The valves are installed at the upper end of border levees at distances 100 feet apart, making it possible to irrigate two strips from one valve. Where the strips are 25 feet wide, short lengths of pipe are connected to the portable hydrant, which is placed over and attached to a valve, and four strips are watered therefrom. In this way the cost of valves is materially reduced.

In 1917 S. H. Beckett, then irrigation engineer of the Bureau of Public Roads, made an examination of the Byron-Bethany irrigation district on the west side of the San Joaquin Valley to outline a suitable method of irrigating alfalfa. Part of the soil of this tract contains a large amount of silt mixed with clay, which it is difficult to

⁴ BECKETT, S. H., and ROBERTSON, R. D. THE ECONOMICAL IRRIGATION OF ALFALFA IN SACRAMENTO VALLEY. Calif. Agr. Expt. Sta. Bul. 280, p. [273]-294, illus. 1917.

moisten to the required depth, and Mr. Beckett had this kind of soil in mind as well as the lighter silty loams in offering the following suggestions:

(1) Wherever the natural contour of the land permits, the border system of leveling should be used. The maximum length of these border strips should not exceed 1,000 feet on the silty clay loam and silty clay soils, and 660 feet on the lighter silty loams.

On the heavier soils the width of checks should not exceed 40 feet. A maximum width of 50 feet may be used on the light soils.

These maximum widths are selected for the following reasons: In the heavier soils, which absorb water more slowly, small irrigation heads must be used. If the border strips on these soils exceed a width of 40 feet with the small heads it is extremely difficult to get an even spread of water over the entire width of border strips. On the lighter soils it is assumed that the irrigation head may be increased, permitting the use of the wider strip.

In the preparation of these lands for irrigation, the grade or slope of the border strip is by far the most important factor. To reduce the rate of flow of water over the land to a minimum and to permit a reasonable penetration of moisture into the soils, the heavy grades within the strips must be eliminated. On the heavier soils this grade may range from 1 to 3.5 inches per 100 feet, while on the lighter types 6 inches per 100 feet should not be exceeded, the most desirable grade being about 3.5 inches per 100 feet. Here it is well to understand that the movement of water over the borders is affected by the thickness of the stand of alfalfa as well as the length of the period between cutting and irrigation. A 100 per cent stand is one of the most effective means of getting an even spread of water over the land.

Too much emphasis can not be placed on this question of grades, for it is impossible to obtain satisfactory results in the irrigation of heavy soils on grades of 6 inches or more per 100 feet, especially if the border strips are not level from side to side and if the stand of alfalfa is poor.

(2) Wherever the contour of the land will not permit these grades to be used, contour borders may well be substituted, in which any desired grade may be maintained. The average width of these border strips will depend upon the contour interval between the levees. On the heavier soils this interval should be reduced, thus narrowing the average width of the strip.

(3) Irrespective of the type of border strips used, the land within the strips should always be carefully leveled. The standard practice is always to level the strip so that not more than 0.1 foot difference in elevation is to be found in its width. This insures an even spread of water over the entire soil surface. On heavy fills allowance must also be made for settling; this avoids the formation of pot holes and prevents scalding of the alfalfa.

(4) On all types of border strips on heavy soils surface drainage must be provided for. This means the construction of "open-ended" strips. In this construction the most common practice is to extend the levees to within 10 to 20 feet of the lower end of the borders, thus allowing the excess water to pass off along the lower ends of the strips, where it may be collected and redistributed on the next tier of strips. Occasionally the border strips are drained through boxes into ditches serving the lower area, although this method is not extensively used. The object of drainage is to prevent scalding of the alfalfa, due to submergence for a long period during the hot summer days.

(5) The types of border strips recommended above call for small heads of water. On the heavier soils the head will not exceed 2 cubic feet per second for each acre contained within the strip, with fractional acreages in proportion to this amount. As an example a strip 660 feet long and 40 feet wide contains approximately 0.6 acre. The maximum flow turned into it, therefore, should not exceed 1.25 cubic feet per second. Under field conditions the irrigator soon learns how the various portions of his field take water, and a uniform irrigation then becomes a matter of judgment in splitting the irrigation head to obtain the best results.

(6) The size of the levees to be built depends on the size of the irrigation head used, the effect of harvesting machinery in wearing down the levees, and finally on whether the field is to be pastured.

On a straight border system the settled levee in these soils should have a height of at least 6 inches and a base width of at least 5 feet. Under severe wear of farm machinery in crossing the levees at an angle or where the area is

to be pastured the size of the levees should be materially increased, the minimum settled height being at least 8 or 9 inches, with a base width of about 6 feet.

(7) Although in the above discussion very definite suggestions have been made, the best designed system possible may be a complete failure, owing to improper handling of the water and poor judgment on the part of the irrigator. With abuse rather than use, any irrigation system may easily become a burden to the community in which it is located.

The Modesto and Turlock irrigation districts of the San Joaquin Valley, although organized in the late eighties, used little water until 1902. The structures which formed part of the original systems were of wood, but these are being gradually replaced by more permanent material. Figure 28 shows a portion of one of the distributing canals of the Turlock district lined with concrete in which is inserted an automatic check gate and drop. A turnout from one

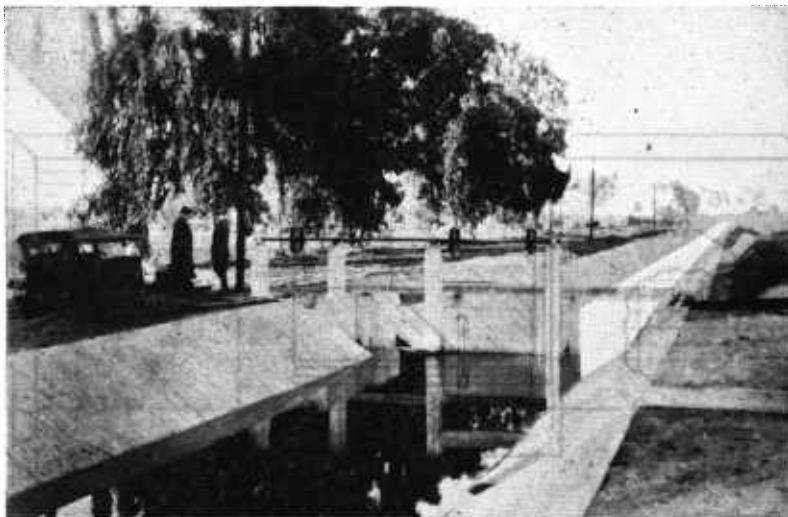


FIG. 28.—Concrete-lined lateral with automatic check gate and drop on Turlock irrigation district, California

of these lined canals, consisting of two or more joints of concrete pipe projecting out of a concrete box, the opening of which is controlled by wooden flash boards, is shown in Figure 29. Another turnout consisting of concrete walls, a concrete pipe, and metal gate is shown in Figure 30.

In the southern end of the San Joaquin Valley, at Wasco, Calif., a large tract has been prepared for border irrigation. This tract was prepared for irrigation about 25 years ago by dividing it into large contour checks, a method then commonly practiced in that part of the State. These being unsuited to modern requirements, the heavy levees are being leveled and border strips 33 to 40 feet wide and 660 feet long formed instead. In this work of transformation the tract was divided into fields to conform to the topography of the land, a contour survey made, and ditches located, extending west as well as north and south from the several pumping plants. These ditches have a grade of about 2 feet per 100 feet, with a free-

board of 5 feet, and are elevated far enough above the graded surface to permit water to a depth of 5 to 7 inches to flow over the land. After the tract was roughly leveled by a wooden float or drag drawn by a tractor, as shown in Figure 31, the borders were staked off and marked by a reversible disk without stagger. The borders were made by using first a two-mule plow, followed by a four-mule disk. After the borders are made, the space between each pair is leveled. The appearance of the borders and intervening spaces at this stage is shown in Figure 32.

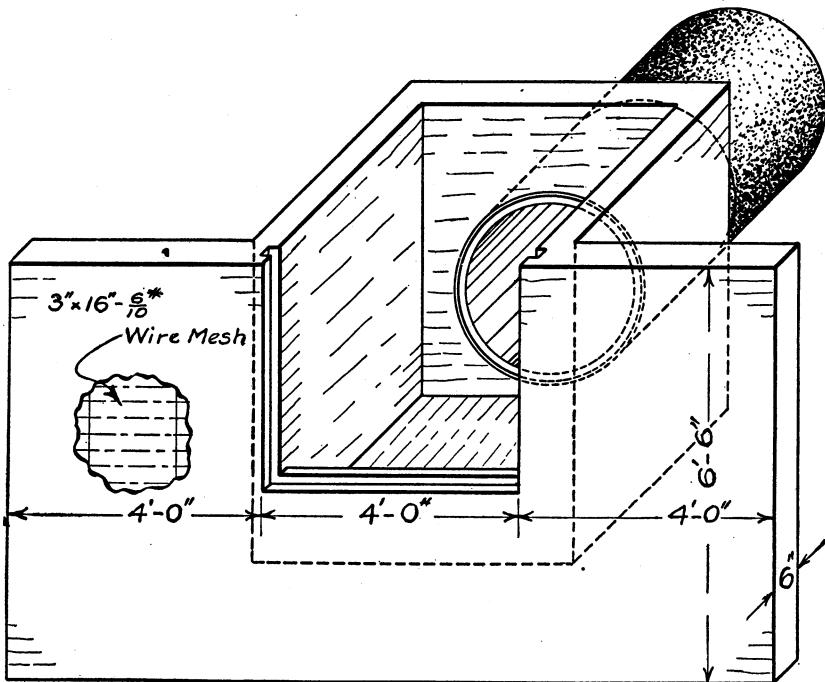


FIG. 29.—A farmer's turnout from lateral

In the Imperial Valley, for all crops that are irrigated by flooding, the border method is by far the most common. At first the border strips were made too long and too wide and little was done to adapt the size of border and the head of water used to the soil type. In more recent years many of the long border strips on porous soils have been shortened by building additional head ditches, and the heads of water on compact soils have been reduced to allow a deeper penetration of moisture. These and other modifications of former practices are recommended by Packard⁵ as a result of investigations carried on from 1914 to 1917 in cooperation with the Bureau of Public Roads. The following paragraphs are extracted from Mr. Packard's bulletin:

⁵ PACKARD, W. E. IRRIGATION OF ALFALFA IN IMPERIAL VALLEY. Calif. Agr. Expt. Sta. Bul. 284, p. [67]-84, illus. 1917.

METHOD OF IRRIGATION RECOMMENDED FOR POROUS SOILS

The great danger in all sandy or porous soils is that too much water will be applied and a high-water table thus formed. This condition is already prevalent in some sections where sand overlies clay. The clay tends to retard the downward movement of the water, and as a result there is an accumulation of water above this stratum, which gradually rises toward the surface as irrigation continues. This rise of water table can be prevented in a majority of cases by adopting one or all of the following suggestions.

The border strips for irrigation on this type of soil should usually not exceed one-eighth of a mile in length and, if necessary, not more than 25 to 30 feet in width in order that the water applied may reach the lower end without oversaturating the upper end. There are many fields in the valley where water has been run from a quarter to a half mile on these types of soil, with the inevitable effect of adding too much water at the upper portion of the field, which, of course, results in a rise of water table. The exact length and width

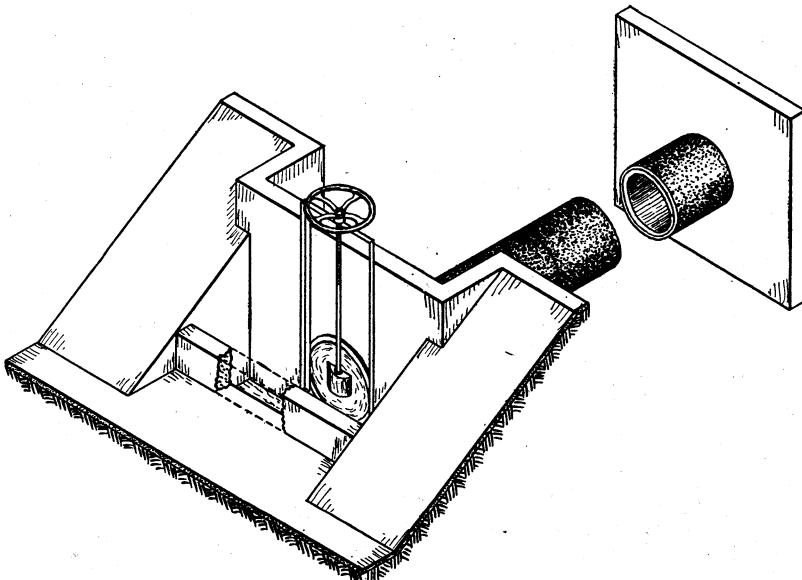


FIG. 30.—A turnout from main lateral

of the lands must depend on the condition of the surface and the degree of porosity of the soil. If the soil is very sandy the strips should be both narrow and short in order to allow a quick irrigation.

In addition to using smaller strips than are now being used, it would be an advantage in nearly all cases to use much larger heads of water than are at present used on this type of soil. A small head will often disappear so rapidly at the upper end that it takes a very long time to cover the field. The size of head must conform to the size of the strip and the character of the soil, the point being to run the water so quickly over the land that an excess above the requirements of the plants will not be added to any part of it. A head of 3 to 8 cubic feet per second for the very sandy soil and from 2 to 4 cubic feet per second for the more compact sandy loams would not be too great. A soil auger can be very effectively used in determining the soil-moisture condition where one is uncertain regarding the moisture penetration.

METHODS OF IRRIGATION RECOMMENDED FOR MEDIUM SOILS

The sandy loam soils are easily irrigated, although too much or too little water is sometimes applied, with the usual results. There is no good excuse, however, for not having a good moisture condition in these medium soft soils.

If the alfalfa does not grow as rapidly as desired, an investigation should be made of the moisture condition in the soil by the use of a soil auger or a spade. If the top soil appears too dry before irrigation it would perhaps be wise to give the field an additional light irrigation between cuttings.



FIG. 31.—Rough leveling land for border irrigation near Wasco, Calif.

METHOD OF IRRIGATION RECOMMENDED FOR COMPACT SOILS

The problem on the hard type of soils is to get the water deep into the soil in sufficient quantities to maintain rapid growth.

In many cases the fact that the surface has been irrigated is taken as evidence that the water has soaked in, while in reality only the top 6 inches have been wetted. It is very common to find dry soil at a depth of $2\frac{1}{2}$ to 3 feet in

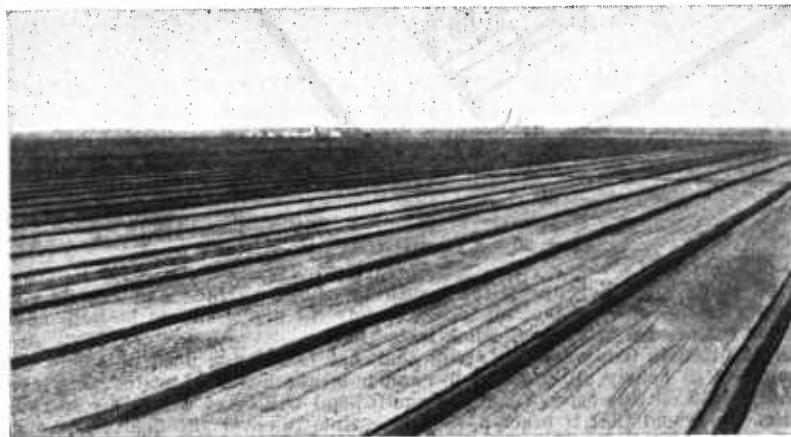


FIG. 32.—Newly made borders on the Hoover farm near Wasco, Calif.

these heavy soils. In order to get proper penetration, the following recommendations should be followed out.

The border strip should be from an eighth to a quarter mile long, very seldom running one-half mile, as is now a common practice. It is difficult to handle water properly on long strips, as a flooding of the lower end can seldom be avoided. On land that is comparatively flat, borders 50 to 100 feet apart are satisfactory, but when the land is at all steep, strips should be narrowed down to 25 to 30 feet wide, so that a small head will cover the surface evenly.

In order to get proper penetration, it is necessary to run a comparatively small head for a long time. Fields which yielded from $2\frac{1}{2}$ to 3 tons per acre per year have been made to double the yield through this system of irrigation. A small head of water requires much longer time to travel over the field than a larger head and allows of a better penetration. Land which could be wetted only to a depth of 3 feet when large heads were used were successfully wetted to a depth of 5 and 6 feet by the use of smaller heads. The effect of smaller heads running for a longer time is more noticeable with furrow irrigation than with flooding, but the effect is marked in both cases.

Formerly wooden border gates were used throughout in the Imperial Valley, but owing to unfavorable climatic conditions the wood, when in contact with earth, soon decayed, and structures of more permanent materials have taken their place. The border gate now

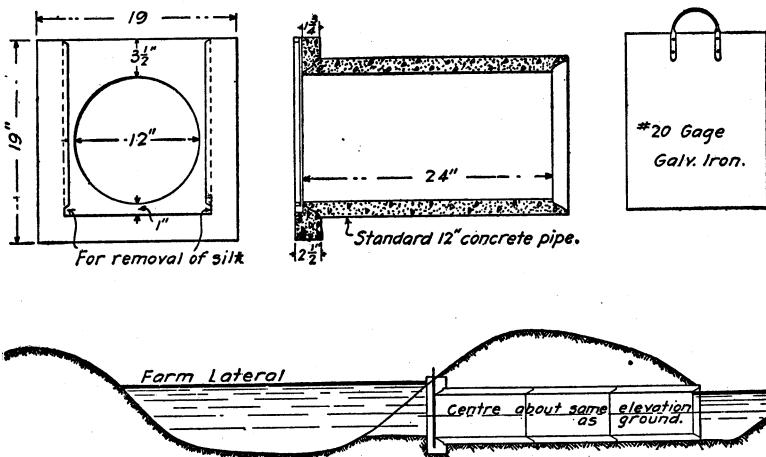


FIG. 33.—Imperial Valley border gate

very generally installed is shown in Figure 33. It consists of a joint of concrete pipe, usually 12 inches in diameter, to which is precast a bulkhead of the same material. The gate proper is made of galvanized iron which fits into grooves in the bulkhead, and at the bottom of each groove is an opening for the removal of sand and silt. The capacity of a 12-inch gate is about 3 second-feet when laid so that the center of the pipe is on a level with the ground surface. One or two extra joints of pipe are used with each gate.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

January 14, 1928

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